Using Excel to Analyze Experimental Data, Part I

Tips and Tricks that Simplify Handling Large Amounts of Data

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NASA Advanced Supercomputing Division

Preface

- The webinar assumes basic knowledge of Excel
- The advice here is somewhat unconventional and is influenced by:
  - The author's computer science background
  - The author's experiences with large workbooks for analyzing
    - Benchmarking data
    - PBS usage data
- There is a lot of material here
  - You may need to invest some time after the talk to experiment with the techniques described
  - To help with that there is an accompanying workbook:
    - Excel_Webinar_Examples.xlsx
- Some of the techniques here are Excel-specific
  - Some will not work with OpenOffice, Numbers (Apple), or Google Tools

Question? Use the Webex chat facility to ask the Host

Excel as a Model of Computation

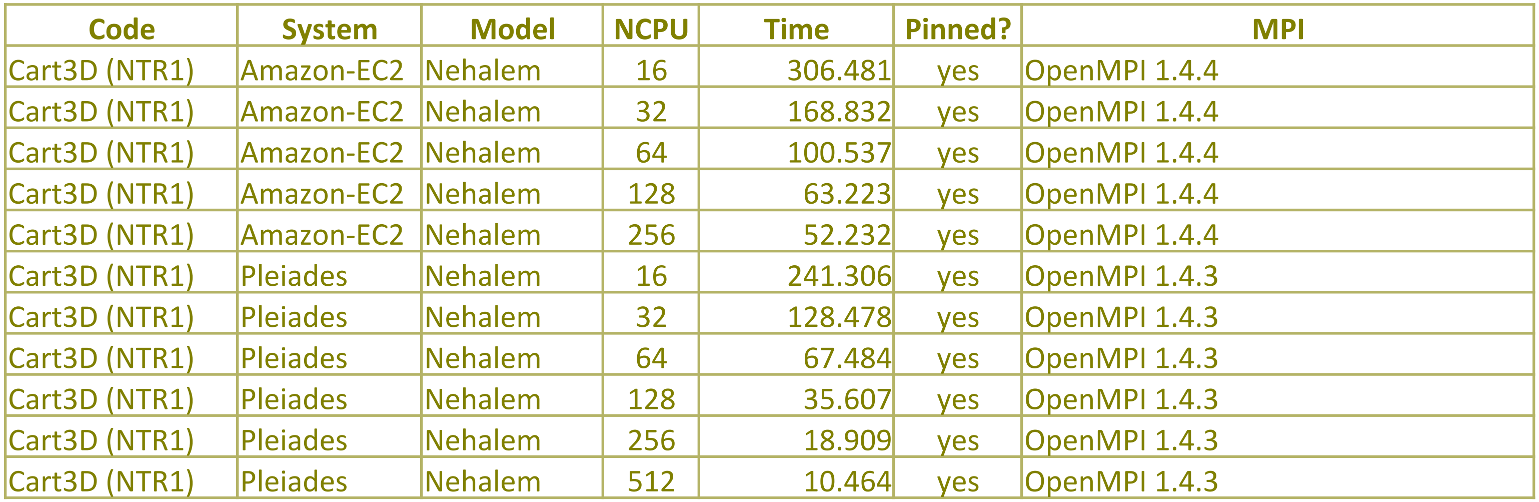
- A table of cells containing
  - Input values
  - Formulas for calculating values

	A	B
1	2	=A1+A2 5
2	3	=A1*A2 6

- In computer science terms: a *functional* program
  - Just expressions (functions) being evaluated
    - There are no side effects
    - “Answers” appear in one or more of the cells
  - Contrast with an *imperative* program
    - A sequence of statements changes a *program state*
  - Functional advantages: easier to write & reason about
  - Caveat: not considering Visual Basic macros or “goal seek”

Analyzing Data: The Power of a Large Table

- Suppose: lots of data from a “parameter” study
  - E.g. performance scaling
- Tip: organize as one large table of records
  - Where each record has all parameter settings
  - Example: performance scaling study of Amazon cloud



Code	System	Model	NCPU	Time	Pinned?	MPI
Cart3D (NTR1)	Amazon-EC2	Nehalem	16	306.481	yes	OpenMPI 1.4.4
Cart3D (NTR1)	Amazon-EC2	Nehalem	32	168.832	yes	OpenMPI 1.4.4
Cart3D (NTR1)	Amazon-EC2	Nehalem	64	100.537	yes	OpenMPI 1.4.4
Cart3D (NTR1)	Amazon-EC2	Nehalem	128	63.223	yes	OpenMPI 1.4.4
Cart3D (NTR1)	Amazon-EC2	Nehalem	256	52.232	yes	OpenMPI 1.4.4
Cart3D (NTR1)	Pleiades	Nehalem	16	241.306	yes	OpenMPI 1.4.3
Cart3D (NTR1)	Pleiades	Nehalem	32	128.478	yes	OpenMPI 1.4.3
Cart3D (NTR1)	Pleiades	Nehalem	64	67.484	yes	OpenMPI 1.4.3
Cart3D (NTR1)	Pleiades	Nehalem	128	35.607	yes	OpenMPI 1.4.3
Cart3D (NTR1)	Pleiades	Nehalem	256	18.909	yes	OpenMPI 1.4.3
Cart3D (NTR1)	Pleiades	Nehalem	512	10.464	yes	OpenMPI 1.4.3

  - Table can be huge, e.g.
    - 1 line for each of the 790k PBS jobs that ran on Pleiades in 2012

Review: Tables and Formulas

- Suppose table has a combination of data and formulas

Code	System	Model	NCPU	Time	Pinned?	MPI	derived value 1	derived value 2
Cart3D (NTR1)	Amazon EC2	Nehalem	16	306.481	yes	OpenMPI 1.4.4	= formula1	= formula2
Cart3D (NTR1)	Amazon EC2	Nehalem	32	168.832	yes	OpenMPI 1.4.4	= formula1	= formula2
Cart3D (NTR1)	Amazon EC2	Nehalem	64	100.537	yes	OpenMPI 1.4.4	= formula1	= formula2

---------------------------------- experiment values ---------------------------------- ------- derived values ------

- When copy & pasting formulas: Excel will "relocate" parts of them
  - Relative references, e.g. **C43**, get changed
  - E.g. In cell **D45**, the reference **C43** is really reference to row-2, column -1
    - Would get relocated to **D43** when pasting in **E45**
- Can protect row and/or column from relocation with a **$**
  - "Absolute" reference examples: **$C43   C$43 $C$43**
  - E.g. **$C43** copied from **D45** becomes **$C44** when pasted into **F46**
- Judicious use of relative and absolute addresses will allow copying down the "derived value" columns
  - (examples on "Big Table" sheet of Excel_Webinar_Examples.xlsx workbook)

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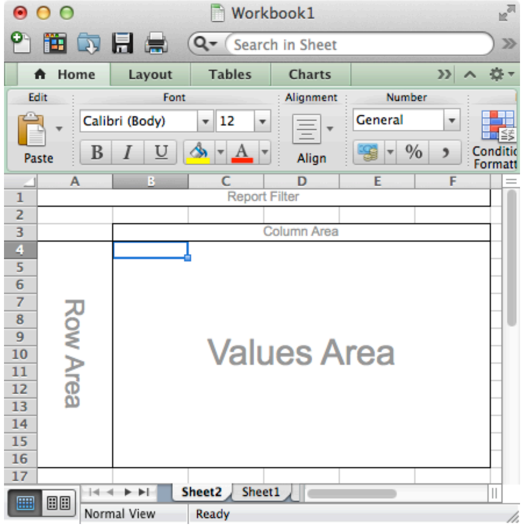
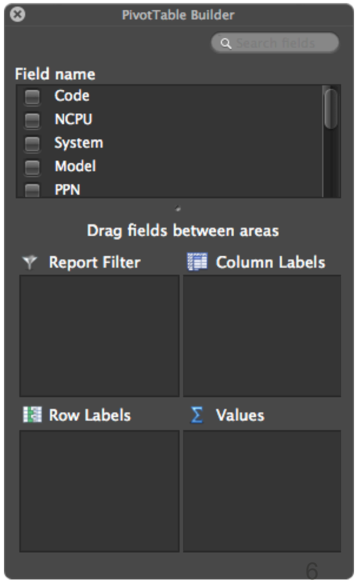
Analyzing Tabular Data: The Pivot Table

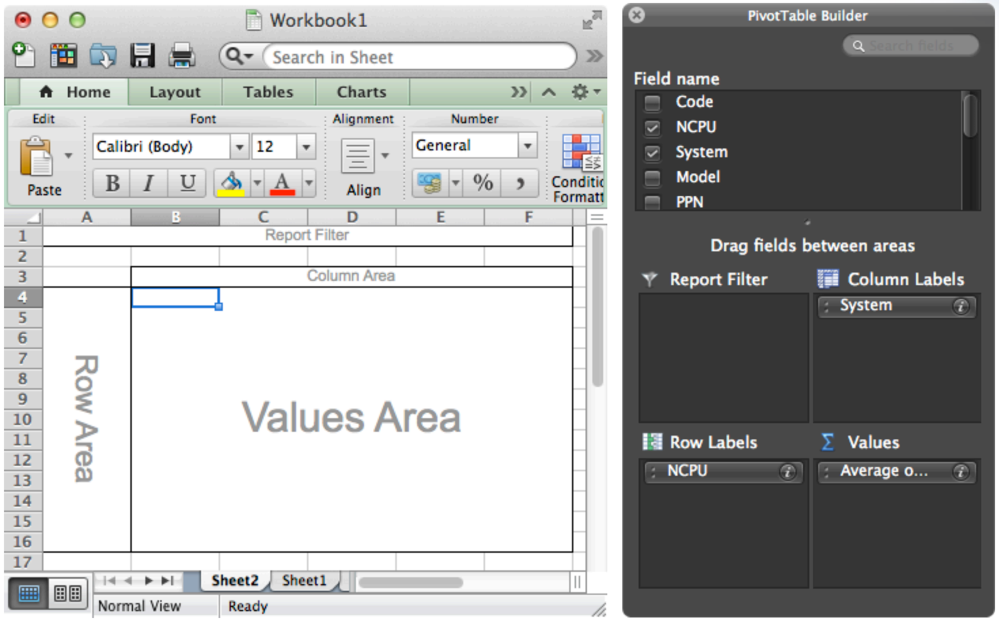
- Pivot Table: a tool for filtering data and applying reductions across similar records
  - Define a collection of buckets so that every record falls into one bucket
  - Select a reduction to be performed across all records in each bucket
- To use: (see “Pivot Table” sheet of examples book)
  - Select all rows & columns (with headings) in table
  - Select menu item **Data:Pivot Table…**
  - Answer questions in wizard
    - **Use a table or range in this workbook** (should be selection)
    - Either **New Worksheet** or **Existing Worksheet**; then **OK**
    - Up pops the Pivot Table builder

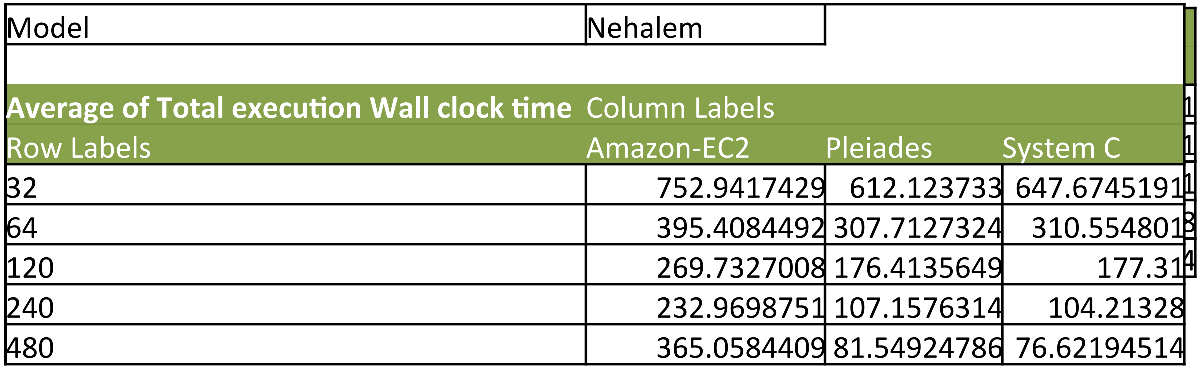




Pivot Table (continued)

- Drag:
  - "NCPU" to "Row Labels"
  - "System" to "Column Labels"
  - "Total execution Wall clock time" to "Values"
    - Click on "*i*" to change reduction to "Average"
- Can add data filters by dragging column header labels to "Report Filter"
  - Then can select values to include/exclude with that filter
  - Here filtering on "Model" (= Nehalem)
- Note: must **Refresh** after source data changes

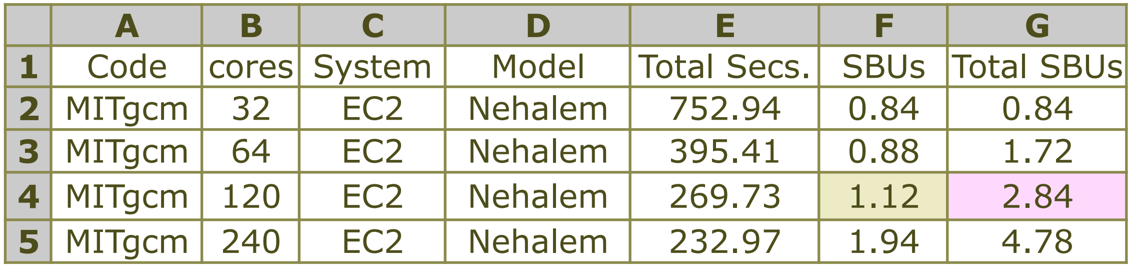




Model	Nehalem		
Average of Total execution Wall clock time	Column Labels		
Row Labels	Amazon-EC2	Pleiades	System C
32	752.9417429	612.123733	647.6745191
64	395.4084492	307.7127324	310.554801
120	269.7327008	176.4135649	177.31
240	232.9698751	107.1576314	104.21328
480	365.0584409	81.54924786	76.62194514

Issues: Handling Changes with Big Tables

- Suppose we have: (try out on “Big Table” sheet)



	A	B	C	D	E	F	G
1	Code	cores	System	Model	Total Secs.	SBUs	Total SBUs
2	MITgcm	32	EC2	Nehalem	752.94	0.84	0.84
3	MITgcm	64	EC2	Nehalem	395.41	0.88	1.72
4	MITgcm	120	EC2	Nehalem	269.73	1.12	2.84
5	MITgcm	240	EC2	Nehalem	232.97	1.94	4.78

=E4/3600*B4/8 =F4+G3

- Inserting a row before row **4** yields:

=E5/3600*B5/8 =F5+G3

  - To fix: recopy formulas from above the insertion to all rows at & below
- Deleting row **3** yields **#REF!** in formulas in column **G** at & below the deletion
  - Again, to fix: recopy formulas from above the change to bottom of table
- Use combination of **ADDRESS**, **INDIRECT** to fix insert & delete
  - The value of **ADDRESS(5, 8, , , “sheet1”)** is **“Sheet1!$H$5”**
  - The value of **INDIRECT(“Sheet1!$H$5”)** is value of **H5** on **Sheet1**
  - For the **G3** can use: **INDIRECT(ADDRESS(ROW()-1, COLUMN(),,,)**
    - Won’t be changed with copy/paste or insert/delete

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Advice: Separate "Program" from "Data"

- To apply the same analysis to data from multiple experiments:
  - Segregate data from formulas
    - Data for each experiment resides on a sheet by itself
    - Can be imported easily from **.txt** file or **.csv** file
  - No "magic numbers" on formula sheets
    - Perhaps on separate sheet (more later)
- This approach will allow all the formula sheets for the experiments to be identical
  - Pull data from data sheet and magic numbers from a parameter sheet
  - Makes it easy to modify the analysis and apply it to all experiments

Trick #1: “Copying” Data to Formula Sheet

- If you want your table to look like:

Code	System	Model	NCPU	Time	Pinned?	MPI	derived value 1	derived value 2
Cart3D (NTR1)	Amazon EC2	Nehalem	16	306.481	yes	OpenMPI 1.4.4	= some formula	= some formula
Cart3D (NTR1)	Amazon EC2	Nehalem	32	168.832	yes	OpenMPI 1.4.4	= some formula	= some formula
Cart3D (NTR1)	Amazon EC2	Nehalem	64	100.537	yes	OpenMPI 1.4.4	= some formula	= some formula

---------------------------------- experiment values ---------------------------------- ------- derived values ------

- Pull the experiment values from their sheet with:

=INDIRECT(ADDRESS(ROW(),COLUMN(),,,”Sheet1”))

  - The value of cell **C17** on **Sheet2** is the one in **Sheet1!C17**

- So, if **Sheet1** starts in **A1**:

Code	System	Model	NCPU	…
Cart3D (NTR1)	Amazon EC2	Nehalem	16	…

- Then **Sheet2** could look like:

=INDIRECT(…	=INDIRECT(…	=INDIRECT(…	=INDI…	=INDIRECT(…	=INDIRE…	=INDIRECT(…	derived value 1	derived value 2
=INDIRECT(…	=INDIRECT(…	=INDIRECT(…	=INDI…	=INDIRECT(…	=INDIRE…	=INDIRECT(…	= some formula	= some formula
=INDIRECT(…	=INDIRECT(…	=INDIRECT(…	=INDI…	=INDIRECT(…	=INDIRE…	=INDIRECT(…	= some formula	= some formula
=INDIRECT(…	=INDIRECT(…	=INDIRECT(…	=INDI…	=INDIRECT(…	=INDIRE…	=INDIRECT(…	= some formula	= some formula

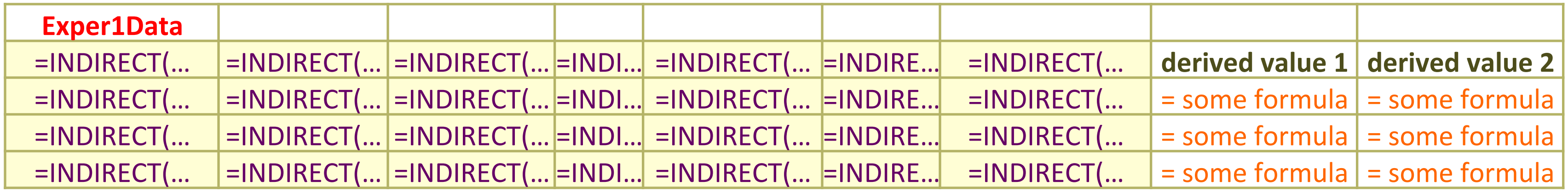
  - Note that the yellow cells all have the identical formula

Trick #2: Facilitating Multiple Experiments

- Each experiment has own data and formula sheet
  - But if all formula sheets refer to **“Sheet1”** they’ll all pull values from there
- Change formula that pulls data to:

=INDIRECT(ADDRESS(ROW()-1,COLUMN(),,,A1))

and put the experiment data sheet name in cell **A1**



Exper1Data								
=INDIRECT(…	=INDIRECT(…	=INDIRECT(…	=INDI…	=INDIRECT(…	=INDIRE…	=INDIRECT(…	**derived value 1**	**derived value 2**
=INDIRECT(…	=INDIRECT(…	=INDIRECT(…	=INDI…	=INDIRECT(…	=INDIRE…	=INDIRECT(…	= some formula	= some formula
=INDIRECT(…	=INDIRECT(…	=INDIRECT(…	=INDI…	=INDIRECT(…	=INDIRE…	=INDIRECT(…	= some formula	= some formula
=INDIRECT(…	=INDIRECT(…	=INDIRECT(…	=INDI…	=INDIRECT(…	=INDIRE…	=INDIRECT(…	= some formula	= some formula

- Can even pull from sheet in another book (if that book is open in Excel)

  [filename]sheetname (**[exp.csv]exp.csv** will work with that CSV file)
- OK, but the formula sheets aren’t quite identical (i.e. cell **A1**)
- Note that sheets can’t be completely identical
  - Excel insists that their sheet names be unique
  - We’ll use that, but must have a formula that gives us our sheet’s name

Trick #3: Getting the Sheet Name in a Cell

- Try out this formula: **=CELL("filename",A1)**
  - Returns sheet name formatted something like:

    nasmac3079:Users:rthood:Research:EC2vsPLD-N:[EC2_DB_v2.0.xlsm]Exper1Formulas
- Extract sheet name, **Exper1Formulas**, with:

  =RIGHT(CELL("filename",A1),LEN(CELL("filename",A1))-FIND("]",CELL("filename",A1)))

  (see "SheetName" in examples workbook)
- Put the above in cell **A1** and all formula sheets can be identical (except for their name)
  - Put a formula in **B1** to calculate experiment data sheet name given that experiment formula sheet name is in **A1**
  - Change formula to pull data values to:

    =INDIRECT(ADDRESS(ROW()-1,COLUMN(),,,B1))
  - If have sheet names like: **Experiment*N*** (formulas) and **Experiment*N*Data** (data)
    - Then formula for **B1** would be: **=CONCATENATE(A1, "Data")**

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Trick #4: Avoiding “Magic Numbers”

- Note that “magic numbers” may be parameters of the analysis
- If parameters are the same across all experiments
  - Could isolate to single sheet and use defined names to reference
    - Search for “Use names in formulas” in Excel help
- If parameters vary across experiments, then 2 options:
  1. Have a sheet with the magic numbers and pull it in at the top of the sheet the way data values are pulled in
     - Will need to adjust **Row()-1** in data pulling
     - Name of parameter sheet could be **Experiment*N*Params**
  2. Put parameters in sheet name and parse them out on the first row
     - E.g. suppose sheet name (**Experiment*N*,Param1**) is in **A1**
       - Experiment name is: **=LEFT(A1,FIND(",",A1)-1)**
       - Parameter is: **=RIGHT(A1,LEN(A1)-FIND(",",A1))**
       - For homework, try parsing parameters of **Experiment*N*,p1,p2,p3** into different cells
     - With this technique, sheets are basically function calls with parameters!

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Recap: A Book with Multiple Experiments

- For each experiment, one sheet for each of:
  - Experimental data, organized as a table of records with a header
  - Parameter sheet for analysis parameters (optional)
  - Formula sheet that pulls data values and per-experiment parameters
- Sheets are named using a pattern
  - Allows data & parameter sheet names to be calculated on formula sheet
  - (see sheets with names beginning with “Exp” in examples workbook)
- When analysis needs to change:
  - Delete all but one of the formula sheets
  - Modify sheet
  - Copy sheet as needed for each experiment
  - Rename copied sheets appropriately to pull correct data
- Issue: Graphs & Pivot Tables on copied formula sheets (more later)

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Next Time

- Review material from this session
  - Additional Q & A time
- Other data manipulation “tricks”
  - Sorting as a functional operation
  - Reductions across multiple sheets
  - Array formulas
- Introduction to Visual Basic for adding functions

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